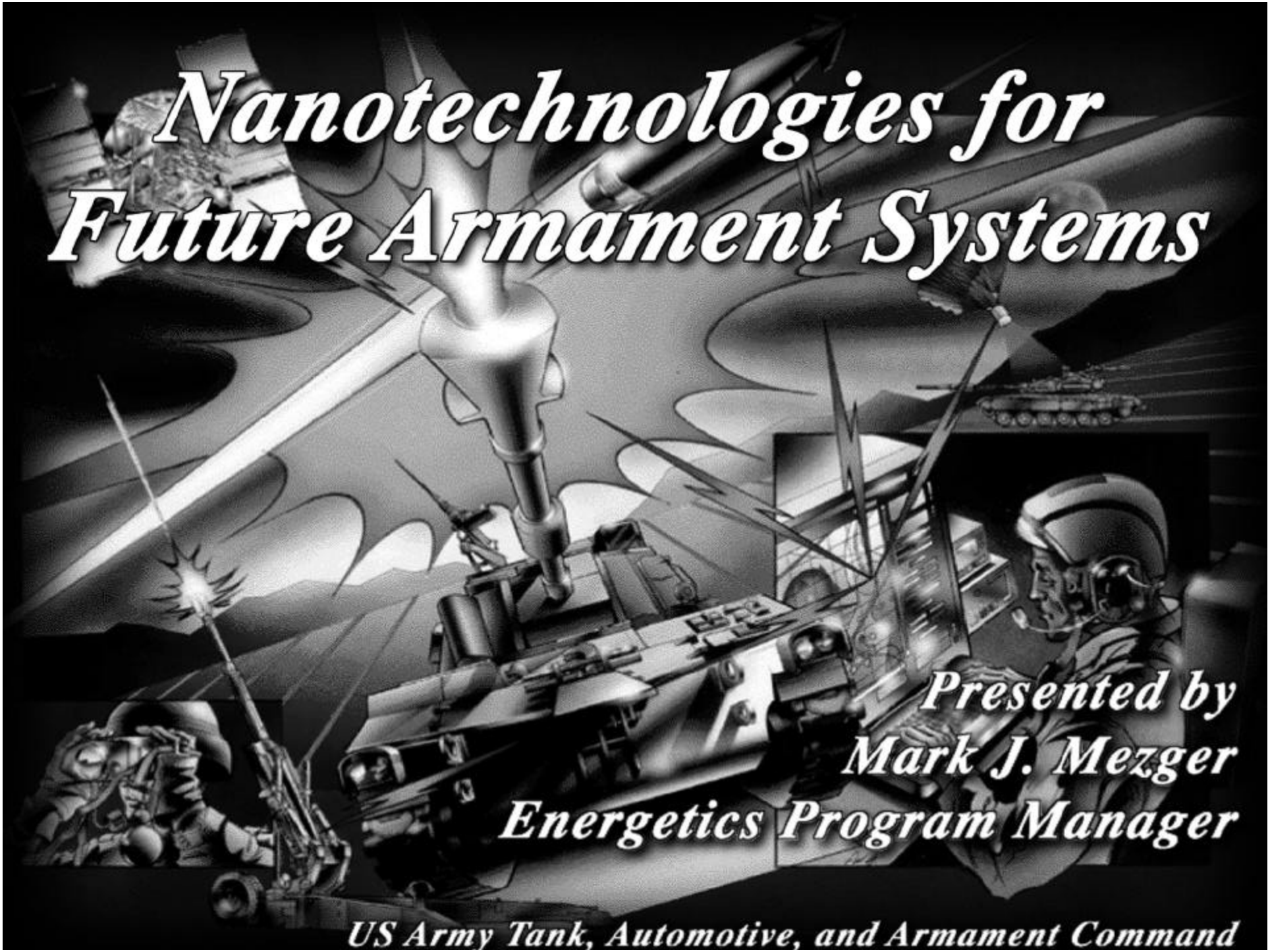
Nanotechnologies for
Future Armament Systems
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What are Nanotechnologies

- *Technology based on the characteristics of small atomic clusters (1 to 100nm) have very different properties than the same materials in bulk and that the physical properties are size dependant*
- *Materials display new chemistry and physics when their size falls below the critical lengths that characterize a particular property such as scattering length, diffusion length, etc.*
- *Properties can be engineered by altering cluster size*
- *Materials can be any type; metals, ceramics, polymers, glasses, or composites synthesized from bottom up from individual atoms and molecules*

TACOM-ARDEC Needs Nanotechnologies

- **Electronics/Optics/Sensors**
  - **Smart Munitions**
  - **IR Sensors**
- **High performance light weight structural materials:**
  - **Warhead and Gun components**
  - **Penetrators**
  - **Armors**
- **Functional Gradient coatings**
  - **Corrosion prevention**
  - **Lubricants**
- **More Powerful Energetics**
  - **Multi-role functionality**
  - **Enhanced Blast**
  - **Non lethal effects**

Why develop this technology for weapons?

- **Nanoparticles**
  - **Energetic Materials**
    - C-H-N-O formulations may have reached a viable energy limit
    - Nanoparticle metals may react in a detonation zone.
    - Nanoparticle metals may enable the energy release process to be engineered for detonations.
- **Carbon Nanotubes (CNT)**
  - **Strength of Materials**
    - Carbon nanotubes (CNT) have a yield strength that is 100 times larger than the yield strength for steel.
    - CNT will enable the mechanical properties of materials to be engineered

Grand challenge is to render small munitions effective against FCS Target spectrum

Material	$D\mathbf{H_f}$
CL-20	393 kj/mol
AlF_3	1510 kj/mol
Al_2O_3	1675 kj/mol

- **Why Now?**
  - **Starting in FY01 there is a massive National Nanotechnology initiative that can be leveraged ($412M)**
  - **This effort is anticipating ($528M) in FY02**
  - **National Advanced Energetics program being initiated by OSD ($30M/yr for the next 3 to 5 years**
  - **Affords the opportunity to mature these technologies in time to impact FCS EMD.**

Nanopowder Programs for Munitions Applications

	Army	Navy	AF	DOE
Nanomaterial Synthesis and Characterization				X
Reactive Structural Components for Warheads	X		X	
Reactive Fragments		X		
Micro Energetic Initiators for MeMs S&A Designs	X	X		X
High Energy Explosives Formulations and Processing	X		X	
Metastable Intermolecular Compounds (MIC) materials	X	X		
Structural Materials	X			

What are the technical barriers?

- Barriers to implementation:
  - No established quantitative weapons effectiveness study to verify claims of nano enhanced energetics/warheads
  - Surface area affects and reactivity make processing these materials difficult and hazardous.
  - Nanoparticle metals or Carbon Nanotubes cannot be readily produced economically
  - Methodologies and standards for characterizing these materials do not exist

Approach

- Identify optimal nanopowder characteristics by:
  - Screening different materials (ie compound species)
  - Varying particle size and size distributions
  - Varying the passivation

- Develop nanopowder fabrication alternatives
  - Evaluating different processes
  - Assess producibility
  - Scale-up

- Develop highly filled material processes
  - Rheological characterization of constituents
  - Model and simulate process flows
  - Conduct process runs & Characterize
  - Assess producility and scale-up

- Develop a process for consolidation of metal powders
  - Model and Simulate
  - Conduct process runs & Characterize
  - Assess producibility and Scale up

- Design and LAP Test Vehicle
  - Model & Assess performance
  - LAP hardware & Test

Initial Team Members

- TACOM-ARDEC
  - Chemical and Vapor phase condensation nanopowder production
  - Materials characterization
  - Project coordination
- Stevens Institute of Technology/MPRI
  - Process Modeling and Simulation
    - Nanopowder process development and scale up
    - Nanopowder composite processing
  - Material characterization
- ATK (Thiokol Division)
  - Energetic material fabrication and testing
  - Energetics production processes
- Rutgers.
  - Nanopowder process development
  - Nanopowder production
- General Dynamics(OTI Division)
  - Effectiveness determination
  - Device design and prototype demonstrations
- SAA International
  - Device demonstrations
  - Warhead testing and manufacturing technology implementation

Manufacturing Research,Development, & Education Center for Nanotechnologies

Industry/Academe/Government Affilitated

NanoValley

Purpose:

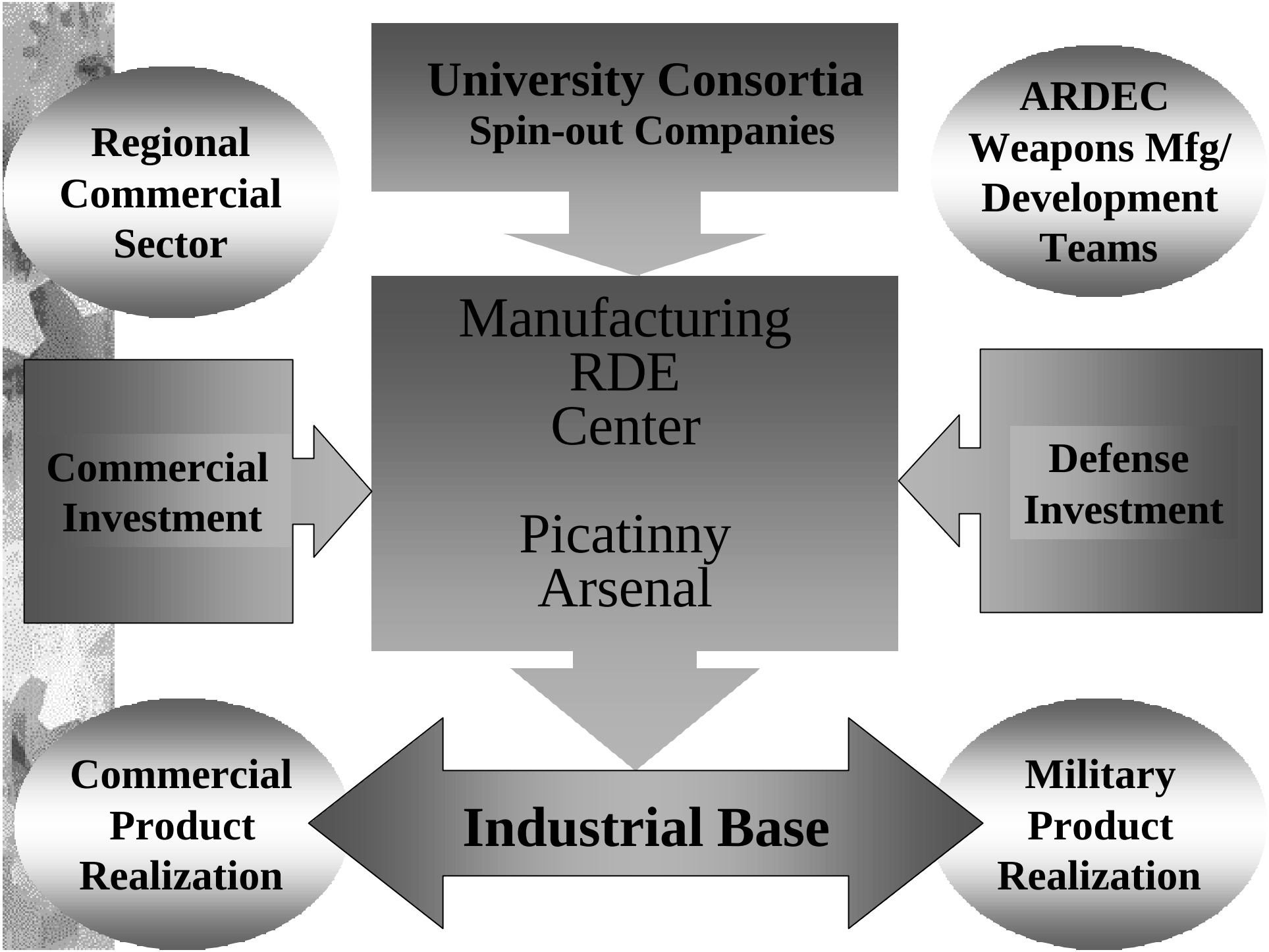
- Establish a regional coalition of universities and educational institutions to conduct research in Nanotechnologies
- Generate an environment that is conducive to business growth
  - Small innovative start-up initiatives
  - New ventures for large organizations
- To optimize the utilization of existing facilities and resources at Picatinny Arsenal.

The Mission:

- To facilitate the development of future manufacturing technologies and to train a competent workforce.
  - To promote research collaboration among regional Academic institutions
  - To accelerate the growth of small “High Tech” businesses
  - To enable new growth areas for large companies
  - To streamline the technology transfer process
    - Establish a manufacturing knowledge base for both the defense and commercial industrial communities
    - Establish new educational opportunities

Initial Start-up FY02

- To exploit regional expertise in Nanotechnologies
  - The Center for Nanomaterials Research(CNR) at Rutgers University has become a focal point for nanomaterials research and collaboration
    - Has a proven track record for building successful businesses
  - The Highly Filled Materials Institute HfMI at Stevens Institute of Technology is a focal point for materials processing and technology transfer to industry
    - Has a long established relationship with many manufacturing organizations in major industrial areas.
- To exploit existing facilities at Picatinny Arsenal
  - The US Army TACOM-ARDEC is the Army's lead laboratory for energetic materials life cycle issues.
    - Has an established link between weapon developers and the defense industrial base
    - Existing facilities include:
      - Laboratories for hazardous operations
      - Prototype pilot facilities


University Consortia
Spin-out Companies
Regional Commercial Sector
ARDEC Weapons Mfg/ Development Teams
Manufacturing RDE Center
Picatinny Arsenal
Commercial Investment
Defense Investment
Commercial Product Realization
Industrial Base
Military Product Realization

Manufacturing R&D Center Initial Ventures for FY02
Picatinny of the Future

Training Center

Skilled Labor Development

University Intellectual Property

Post Graduate

Bachelors

Apprenticeship

Learning
Linked to
mission

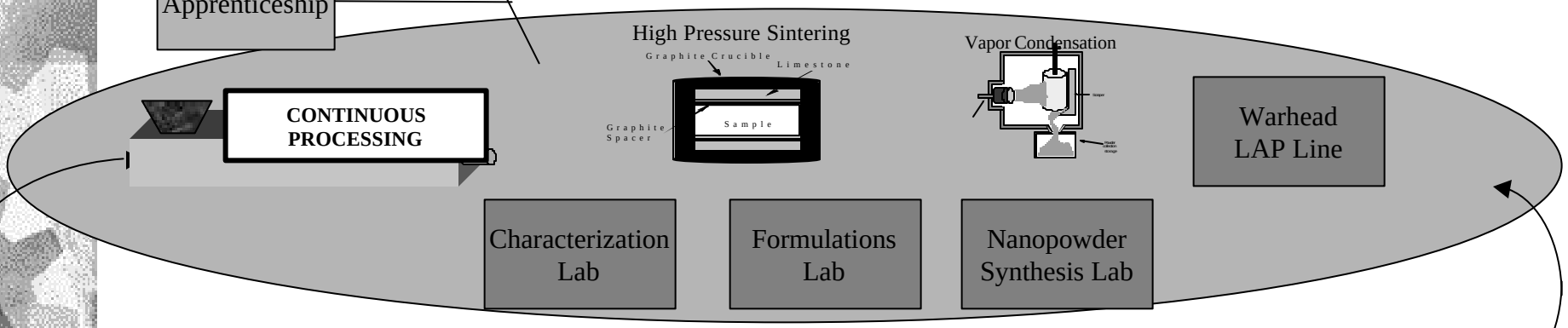
SIT
MPRI

Rutgers
HPS

Rutgers
NEI

Rutgers
NTI

Rutgers
DMI



ARDEC Prototype Manufacturing Lines

Prototypes proven to Industry facilitating commercialization

Major Technology Areas

- Technology areas:
  - Energetics
  - Pharmaceuticals and Biological Materials
  - Chemical Processes
  - Advanced Composite Materials
  - Functionally Gradient Materials
  - Special Coatings
  - Electronics, Sensors, and Micromachines
  - Miniature Power Sources and Fuel Cells
  - Metastable Ceramics

Future Growth Beyond FY02

- University Coalition
  - As research from the national initiativematures it is anticipated n FY03
    - Additional NJ Institutions
      - NJIT
      - Princeton
    - Pennsylvania Institutions
      - Drexel University
      - University of Pennsylvania
      - Penn State University
      - Ben Franklin Institute
      - Nanotechnology Institute of Pennsylvania
- New business spinouts
  - Rutgers anticipates adding 1 new organization every 6 months
  - As the weaponization efforts mature processing information may lead to alliances with several major companies in different industries
    - May also enable spinouts
  - SIT/Rutgers/ARDEC collaboration may produce patent able technologies for future ventures

Summary

- **An enormous effort to develop nanotechnologies is underway within and outside of DoD**
- **The Army needs to identify which nanotechnologies can be rapidly developed for high payoff**
- **ARDEC has positioned itself to efficiently develop and transition new technology and maximize resource Several key technology insertion windows exist**
- **The Army must exploit this technology**